An observational study of clay delving and its impact on the A2 horizon in sand over clay soils

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Sandy surfaced texture contrast soils in South Australia exhibit a range of limitations regarding their potential for agricultural production. The process of "delving" clay to the surface began in the south east of the state in order to address the limitation of water repellence. Clay delving was seen to mimic the water repellence ameliorating effects of clay spreading, only without the expense of importing the clay. Subsequently it has become clear that the delving process also addresses a number of other limitations associated with sandy soils. This paper discusses some of the improvements observed in the A2 horizons of 12 sand over clay soils. All of the sites exhibited bleached A2 horizons prior to the clay delving. Post clay delving, the region disturbed by the delving tine underwent varying degrees of mixing. This profoundly altered the chemistry and subsequent productive potential of the soil.

Key words: bleached A2 horizon; clay delving; clay spreading; infertile; yield

Introduction

The use of clay applied to the surface of water repellent sands has been practiced by South Australian farmers since the 1970s (Cann 2000). Most of the sands were spread with clay in order to treat a surface horizon that was water repellent due to the presence of hydrophobic organic material, as described in Ma'shum (1989). This water repellence was usually the principle soil limitation cited by farmers undertaking the clay spreading. The practice was widely taken up as producers saw immediate yield gains across a range of sandy surfaced soils. In most cases clay was sourced from pits within a few hundred meters of the spreading site. Once spread (average rate of around 250 tonnes of clay per ha), the clay was generally smeared onto the soil using heavy metal bars, and cultivated into the soil, usually to a depth of no more than 10 cm.

Clay delving began in the South East of South Australia as an attempt to access clay more cost effectively for treating water repellence. Where sandy surface horizons overlay clayey B horizons within around half a meter of the surface, clay could be accessed using modified ripping tines. This involves metal tines (usually about 1 to 1.5m long) set at an angle designed to peel the clay from the B horizon, to travel up the tine and spill onto the soil surface. Desbiolles (1997) provides a detailed description of delving operations and outlines a general design for the machinery used.

The first trials of the technique, including the first prototypes of machines to bring up the clay, were first undertaken in the early to mid 1990's (Groocock, personal communication). Since this time it has become evident that the improvements to soil condition derived from clay delving greatly exceed those from merely overcoming water repellence. One of the main impacts appears to be the alteration of the A2 horizon, which is often a bleached and highly infertile sand in its natural state. Following clay delving, the A2 is often blended with A1 and B2 materials, profoundly altering its clay content, hydraulic properties and nutrition status. This study aimed to assess these changes by measuring chemical soil properties and observational soil description and root growth over a range of situations in the field.

Method

Comparative field descriptions and chemical analysis were made of 12 delved soil profiles (exposed in approximately 2 m wide x 1.5 m deep pits). The soils in their natural state represented a range of Brown Chromosols (2), Red Chromosols (1), Brown Sodosols (2) and Yellow Sodosols (7) (Isbell 2003), with sandy A horizons ranging from 15 cm to 60 cm thick (median A thickness was approximately 35 cm). All exhibited strongly bleached A2 horizons (A2 cation exchange capacities ranged from 0.7 to 3.2 cmol(+)/kg). Sharp texture contrasts were characteristic of all sites, with most B2 horizons being mottled and coarsely columnar. The horizon notation used in this paper is from McDonald *et al.* 1990.

All the sites had undergone clay delving, using a range of locally available delving machinery. The time since the delving had taken place prior to sampling varied from six months to seven years. The spacing between the delving tines varied from around 1 m to around 1.8 m (median of 1.5 m), so all sites exhibited strips where the soil had been disturbed in the subsurface and subsoil (along the delve lines), and strips where it had not (between the delve lines).

The A1p of all the sites had been relatively homogenised through the smearing and cultivating of the surface applied clay. Consequently, the main comparisons made in this paper comprise the A2 of the soil where the delving tine had not affected soil morphology compared to where the analogous layer that had been modified by the tine. The A2 material where delving had not induced morphological changes was assumed to be reasonably representative of the A2 in its native state, prior to delving taking place. Hand sampling of the A2 was based on segregating the horizon into three readily identifiable soil materials (refer to Table 1). These were the bleached sand of the A2 unaffected by the delve tine, the sandy material from the zone of the A2 mixed by the delving tine, and the larger lumps of clay within the sandy matrix of the delve affected A2.

Results

Observed soil changes

The effect of delving, in terms of the amount of soil disturbance and inversion that was observed, was highly variable between sites. It is probable that differences in design of the delving implement, the soil type, and the moisture content of the soil all contributed to this variability (May 2006). However, of the 12 sites discussed here, all portrayed significant morphological changes to the A1, A2 and B2 horizons.

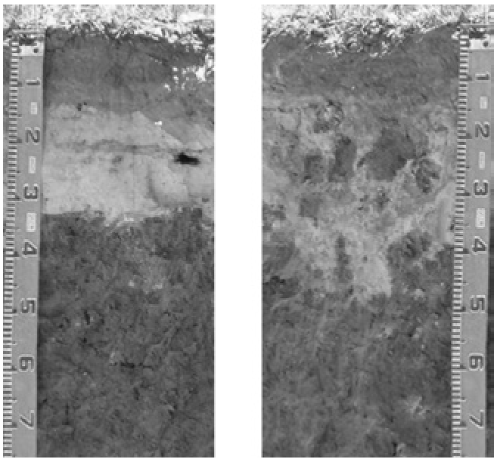

Figure 1: Brown Sodosol- Left hand side shows the profile with the A2 and B2 unaffected by the mixing action of delving. The right hand side shows the A2 and top of B2 affected by delving. The two photos were taken immediately adjacent to each other from the same soil pit.

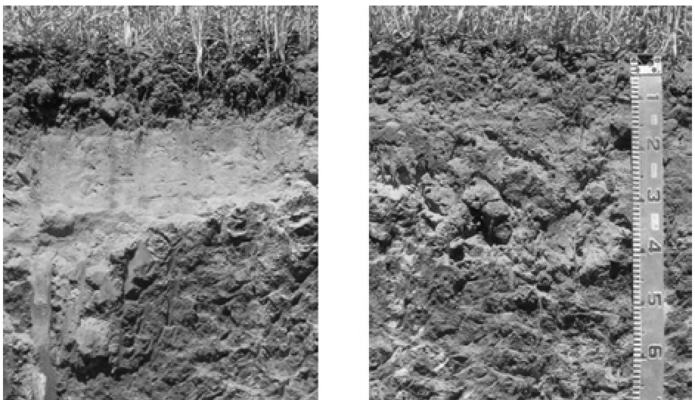

Figure 2: Red Chromosol- Left hand side shows the profile with the A2 and B2 unaffected by the mixing action of delving. The right hand side shows the A2 and top of B2 affected by delving. The two photos were taken immediately adjacent to each other from the same soil pit.

The results of the morphological changes are represented in Figures 1 and 2. All four photographs are of soils that have been delved. The A1 horizons of each of these soils has effectively been clay spread, with the clay brought to the surface via delving having been levelled out uniformly and cultivated into the A1p. The differences illustrated in the two sets of photographs relate to the zone of soil mixed by the delving tine, in contrast with the soil to each side of this mixed zone. Depending on the spacing between the delver tines, the soil with a mixed zone has been observed to comprise between around 10% to over 60% of the soil area within a delved paddock.

Effects of delving on A2 chemistry

The comparative measurements made for this paper were from the A2 horizons of soils to determine the changes relating to soil mixing compared to the relatively unaltered bleached A2 horizons adjacent to the delved zone.

Table 1: Differences in a range of chemical analytes were measured between the identifiable soil materials in the A2 horizons of the 12 delved soils (standard deviations given in brackets).

Mean A2 soil material extractable chemistry				
	Undelved	Delved (sandy material)	Delved (clay lump)	Frequency of sites where results from undelved sand were lower than delved sand (%)
P (Colwell) mg/kg	7.3 (5.5)	12.1 (10.0)	3.9 (3.1)	75
K (Colwell) mg/kg	39.5 (18.4)	60.9 (29.8)	348.3 (140.7)	92
S (KCl-40) mg/kg	3.9 (4.7)	7.3 (7.6)	17.6 (18.7)	92
NO_3^- (KCl) mg/kg	2.9 (2.1)	6.1 (4.5)	10.1 (8.2)	67
Org Carbon (W/B) %	0.3 (0.1)	0.9 (0.4)	0.7 (0.2)	100
Reactive Fe (Tamms) mg/kg	230 (114)	378 (182)	768 (257)	92
CEC (NH_4Cl/ $BaCl_2$) cmol(+)/kg	2.0 (0.9)	3.7 (2.0)	16.1 (4.0)	92
pHCa	5.9 (1.0)	5.6 (0.9)	6.3 (0.5)	27
ETDA Cu mg/kg	0.6 (0.7)	2.8 (2.5)	0.9 (0.8)	75
ETDA Zn mg/kg	0.8 (1.4)	1.5 (1.3)	0.7 (0.4)	83
ETDA Mn mg/kg	1.4 (1.1)	3.8 (3.0)	2.7 (1.6)	100
ETDA Fe mg/kg	70.3 (34.3)	136.5 (72.3)	76.4 (51.6)	92
Boron ($CaCl_2$) mg/kg	0.4 (0.1)	0.6 (0.1)	2.2 (0.6)	92

For all the soil chemistry and nutrition measurements made on the soil materials from the A2, the sandy soil materials visually unaffected by delving were, when averaged, all lower than the sandy material mixed through delving (except for pH). Table 1 shows a summary of the results from soil tests of the unaffected sand, the sandy material mixed through delving, and the coarse clay lumps present in the delved A2. The exception to the trend was soil pH, with eight out of the 11[1] sites measured for pH showing a decrease in pH in the sandy material mixed through delving compared to the undisturbed A2 horizon sand. However, the coarse clay lumps brought into the A2 were generally of a higher pH than both the other identified materials.

Discussion

Delving of bleached sand over clay soils has become a common practice in South Australia over the last 15 years. However, aside from a few papers such as those referenced here, there is very little published on this topic within the scientific literature. Publications relating to clay spreading and to deep ripping, while presenting some relationship to the topic of clay delving, generally do not cover the mixing of A1 and B materials with the A2 horizon (for example, Hall *et al.* 2010). This paper does not attempt to investigate the topics usually presented when discussing ripping or clay spreading, such as non-wetting surface soils, or

[1] One site was irrigated with alkaline ground water, and subsequent pH data was excluded from this analysis.

hard pans, but instead focuses upon the induced changes in soil morphology and chemistry within the A2 horizon.

Observations of the soil profile of delved paddocks show profound changes to the A1 horizon of the soil, analogous to clay spreading. In addition to this, the A2 and upper B horizons of the soil are also significantly altered along the path of travel of the delving tine. Comparisons made between the A2 that has been visually unaltered by the delving, with that of the adjacent soil profile mixed by delving, show stark changes in the A2 properties. In most cases, extractable macro and trace elements are extracted in higher quantities in the mixed A2 soil material. The same is true for the cation exchange capacity of the mixed soil. Soil pH is less clear, however, it appears that the soil mixing may reduce the pH of the sandy material in the mixed A2.

The limited measurements that have been made on plant yield also suggest the subsurface and subsoil mixing has a marked impact on productivity (Rebbeck 2007; Bailey unpublished data). Observations of root abundance have also found marked increases in roots in the mixed A2 (Bailey unpublished data).

Conclusion

Clay delving can result in significant changes to many of the properties of a soils A2 horizon. These potentially include changes to a range of physical, biological and chemical attributes. This paper presents preliminary findings relating to the latter attributes, with indications being that the former two attribute groups are also worthy of further study in relation to affects of clay delving. The main finding of this study has been that, where the soil has been mixed by the delving tine, the A2 is generally enriched in its inherent fertility and its extractable nutrition. The source of these changes are likely to stem from both the mixing of clayey B horizon and the sandy A1 horizon with the low fertility A2 horizon material.

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